CHALLENGS OF COMPARING PROPULSION COOLING CFD TO TEST CHAMBER AND OFF-ROAD PERFORMANCE

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Outline

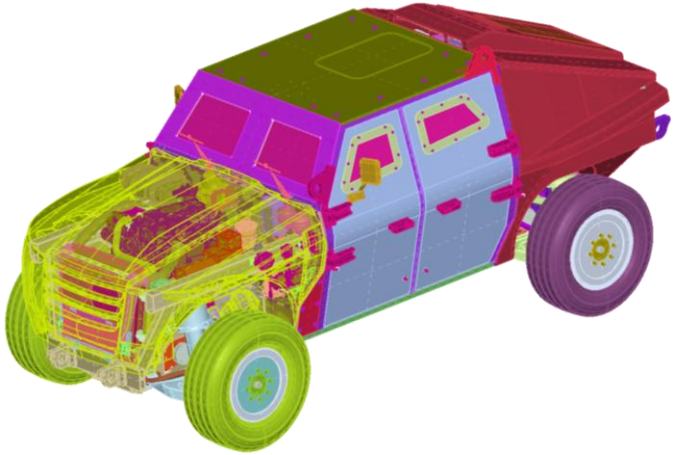
- Introduction
- Methodology
- Wheeled Vehicle
- Tracked Vehicle
- Conclusions

Introduction

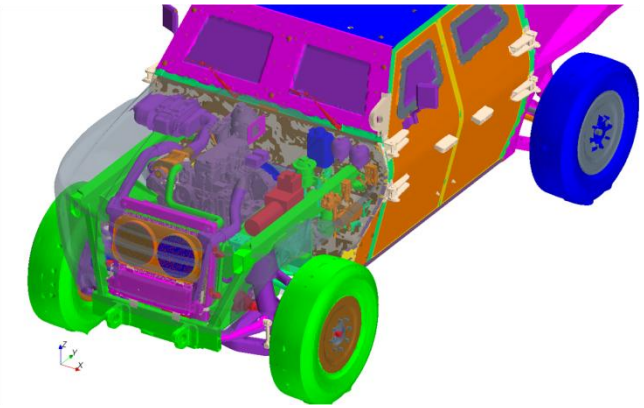
- Full load cooling tests are used to predict vehicle tractive effort, maximum speed, and speed on grade
- Test cells at TARDEC differ in size, inlet, and outlet geometry
- Test cells only approximate off-road condition
- Simulation can be used to compare test cell to off-road conditions
- Comparing simulation to test cell data requires knowledge of test cell geometry and setup

Analysis Method - Preparation

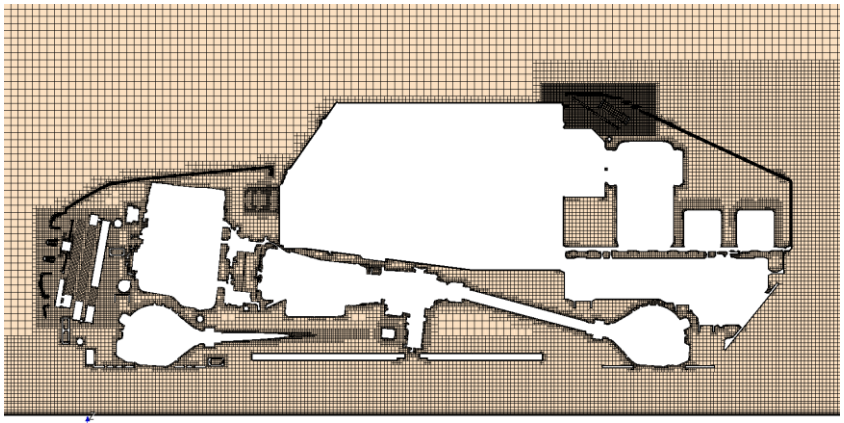
CAD Geometry



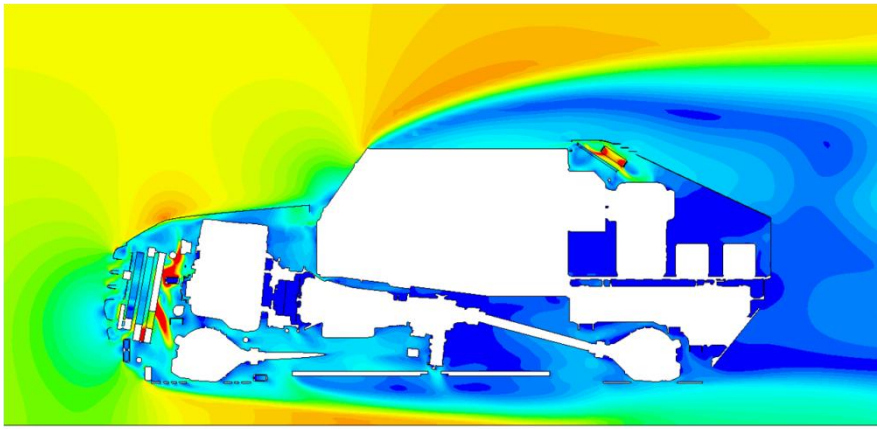
Cleaned Surface
(Wrapping)



Volume Mesh

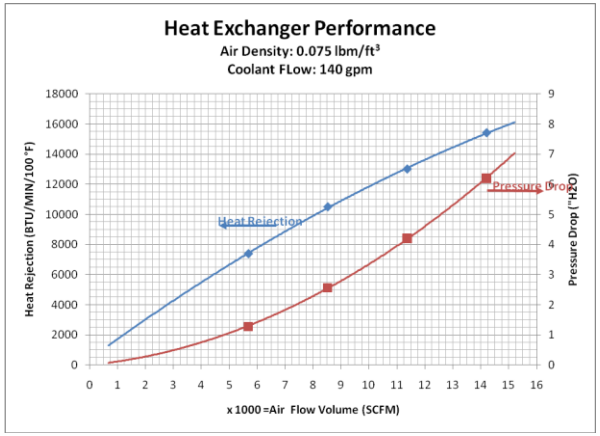


Solution/Post-Processing

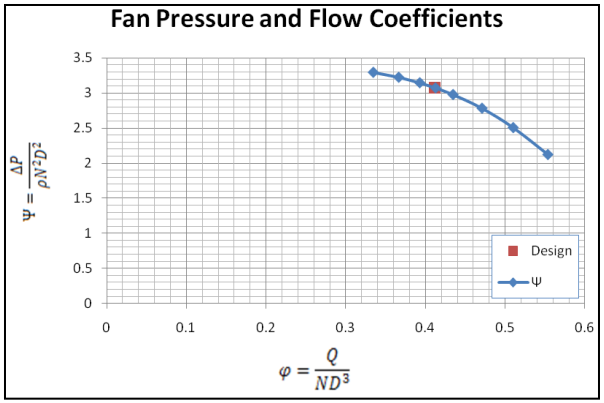


Method - Heat Exchangers and Fans

- Heat Exchanger
  - Model using single stream and porous media
  - Pressure drop vs. flow
  - Heat rejection vs. flow



- Fan
  - Fan geometry typically not available
  - Model using momentum source



- User routine (java class) to automatically update heat rejections and momentum sources

Method - Flow Domain

- Test cell setup is different than off-road simulation setup

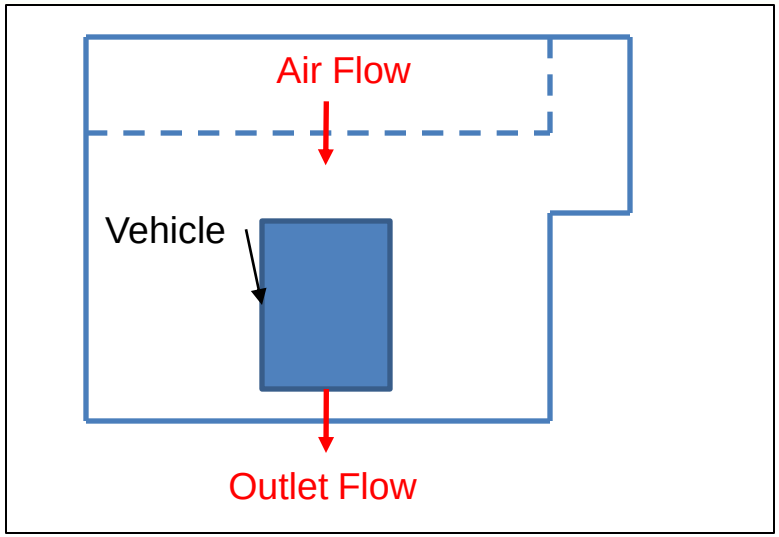
Off-road	Test cell

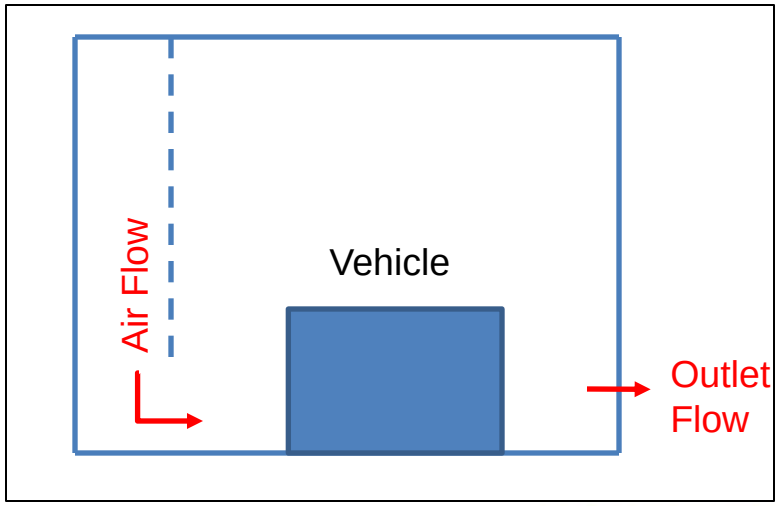
• Sides
  • Symmetry
• Inlet
  • Specified velocity
• Ground
  • Moving ground plane
	• Sides
	  • Walls
	• Inlet
	  • Specified velocity
	• Ground
	  • Stationary wall

To simulate tunnel tests, may need to specify a velocity distribution or model cell inlet geometry

Wheeled Vehicle - Tunnel

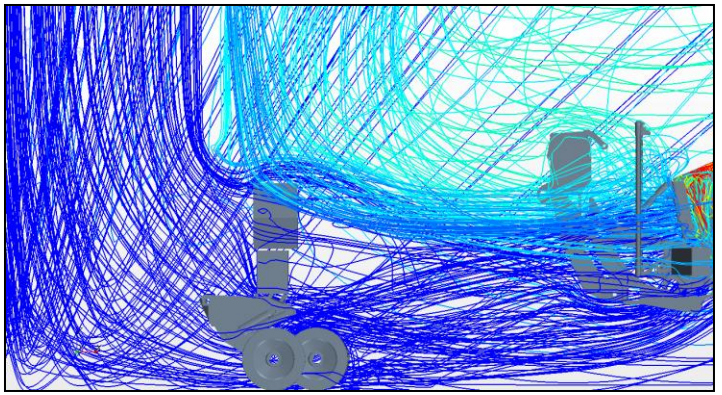
- Tunnel is small relative to vehicle size
- Air flows down from top and turns once it hits the tunnel floor
- Air speed is ~5mph



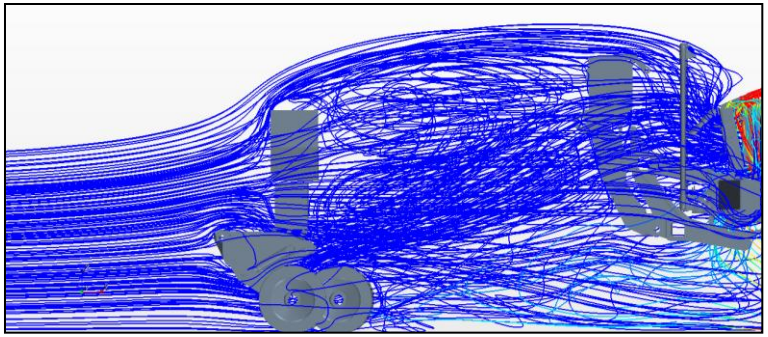


Wheeled Vehicle Cell and Off-Road Streamlines Colored by Temperature

- Warmer air re-circulates back to heat exchanger in test cell
- Underhood flow pattern is altered in test cell



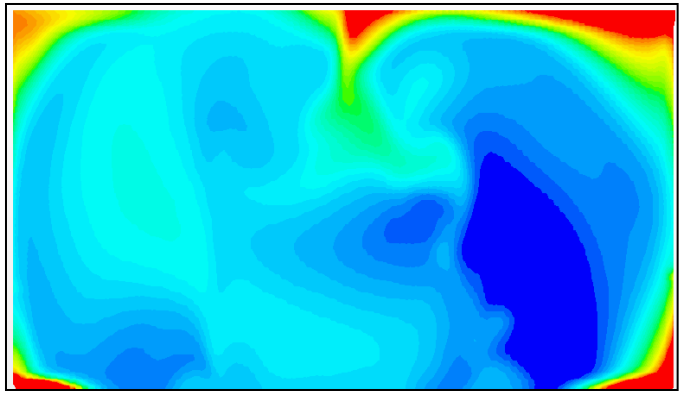
Test Cell



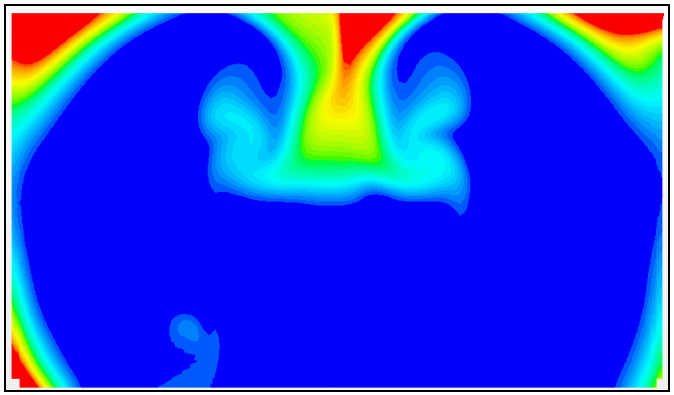
Off-road

Wheeled Vehicle – Temperatures in Front of Condenser

- Mass flow matched well between simulated test, physical test, and off-road simulation
- Temperature at condenser inlet is hotter in test cell due to recirculation



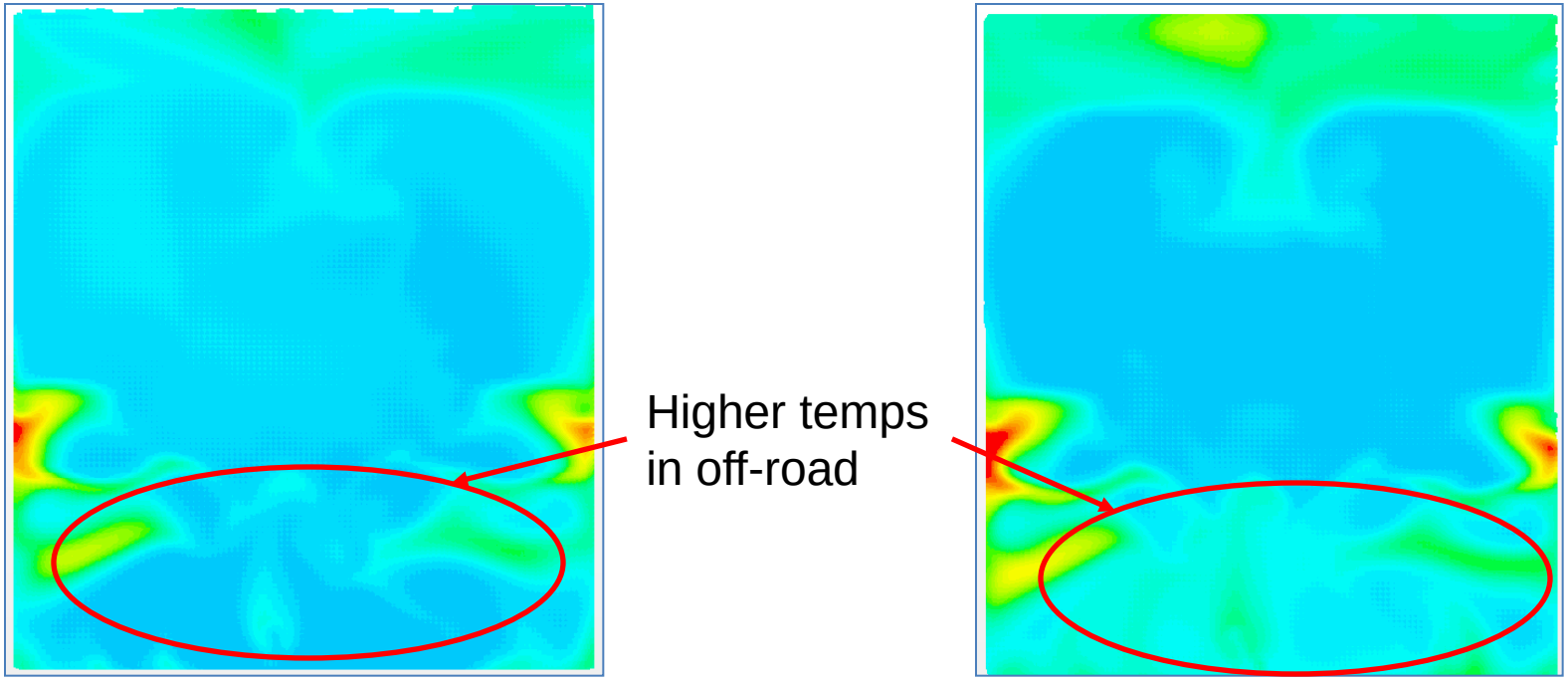
Test Cell



Off-road

Wheeled Vehicle – Temperatures in Front of Radiator

- Air temperature at radiator inlet is cooler in test cell than in off-road condition due to flow hitting the ground as it enters the test cell



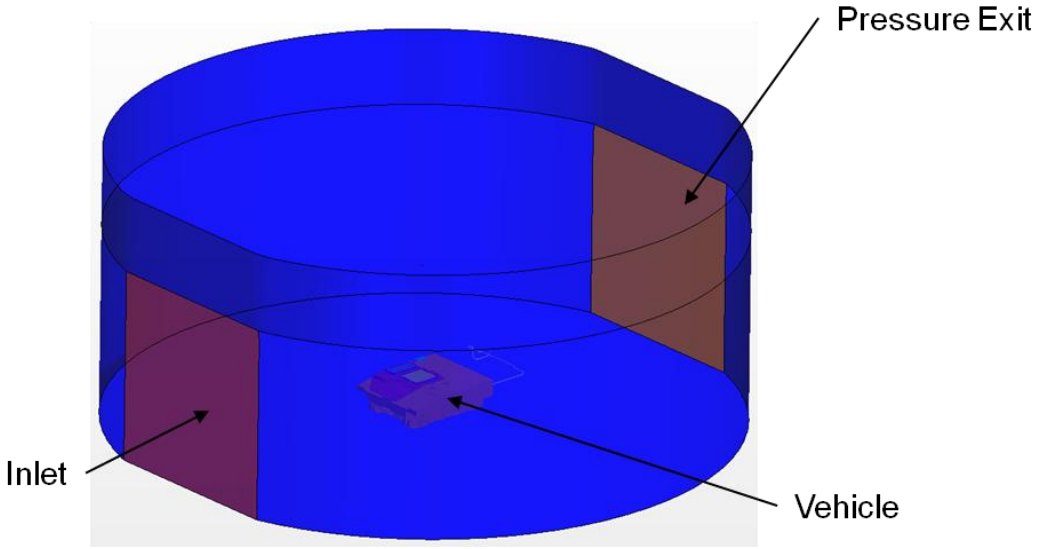
Test Cell

Off-Road

Tracked Vehicle – Test Cell

- Test cell is large compared to vehicle

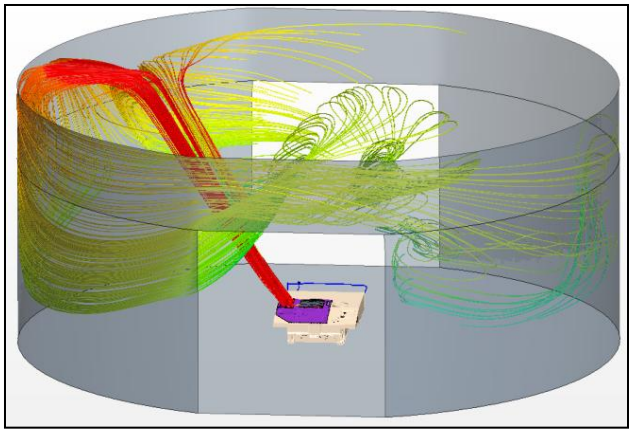
Vehicle in test cell



CFD

Tracked Vehicle – Testing and CFD

- During testing temperature at inlet grille was several °F higher than cell ambient (measured upstream of vehicle)
- At high temperature this can affect test results because of increased inlet temperature to radiators
- Analysis of vehicle in test cell showed flow was not recirculating back into inlet

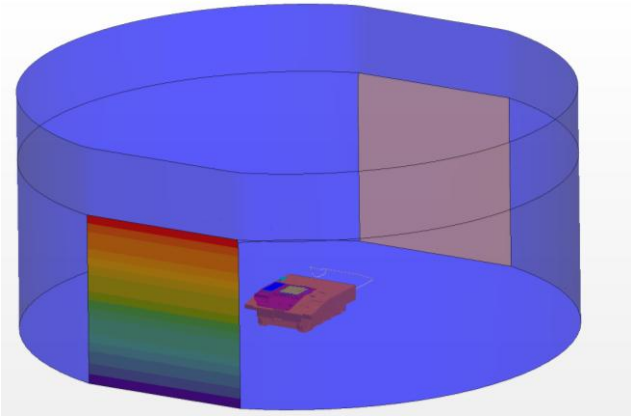


Streamlines from exit grille

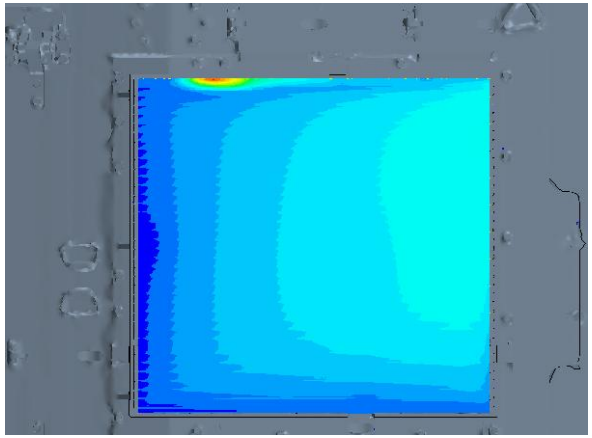
- Investigation showed that there was temperature stratification at the cell inlet

Tracked Vehicle – Temperature Results

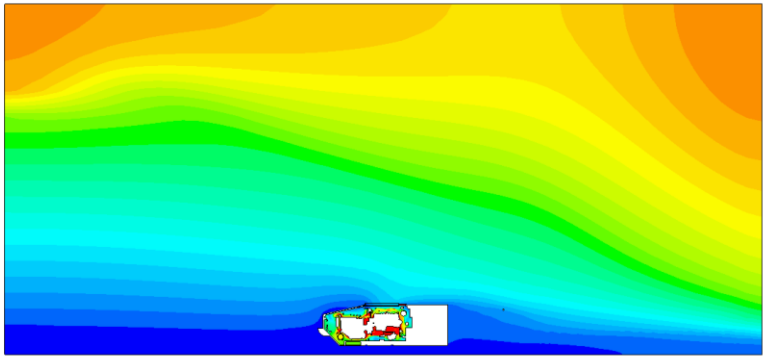
- Stratification at inlet of cell leads to higher temperatures at cooling inlet grille



Tunnel Inlet Temperature



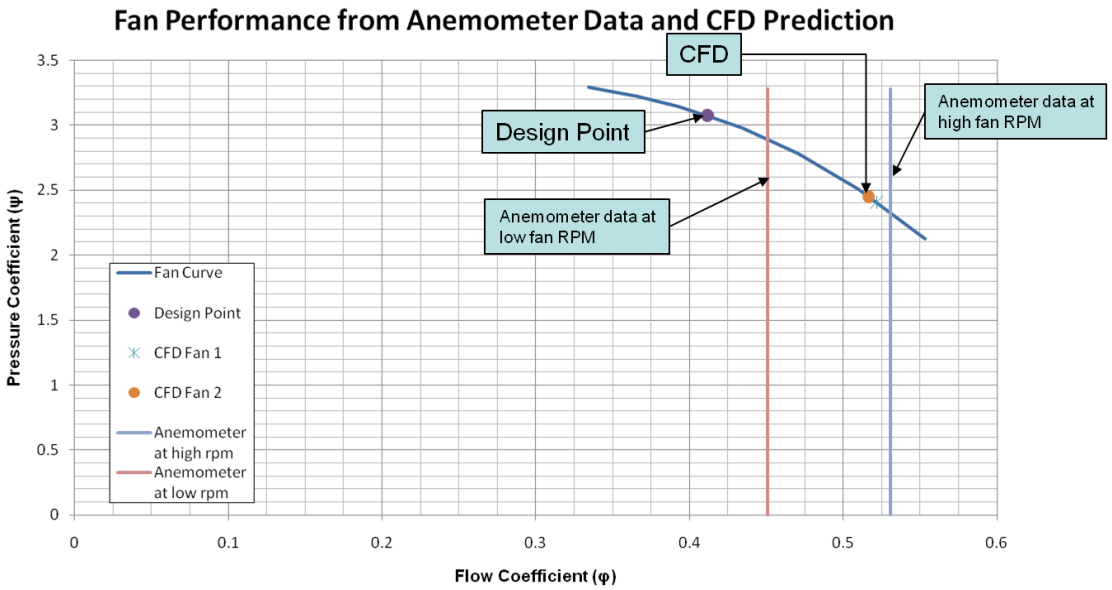
Inlet Grille Temperature



Temperature Along Vehicle Centerline

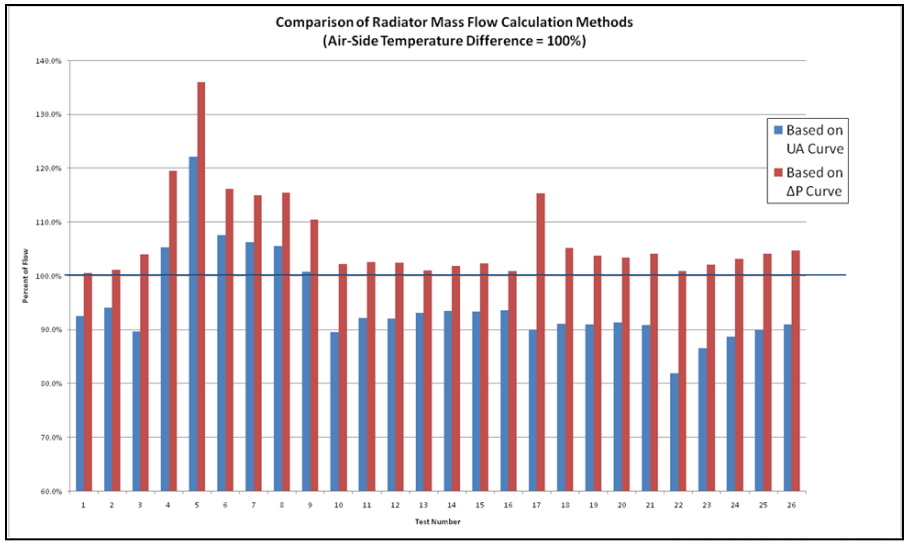
Tracked Vehicle – Operating Points

- CFD matched well with anemometer data taken at similar rpm
- Data and CFD both indicated higher flow than original design



Tracked Vehicle – Flow Rates

- Calculating flow rate through cooling system can be challenging
  - It is not always possible to mount anemometers in cooling system, so alternate means must be used to back out radiator air flow rate
  - Air-side temperature difference can be difficult to measure accurately if there is recirculating flow or equipment problems
  - Helps to compare flows with radiator heat rejection and pressure drop curves to find potential problems



Conclusions

- Obtaining accurate CAD geometry can be challenging, especially for fans
  - Model using momentum source if fan curve is available
  - Note that fan curve is often generated under ideal conditions
- Test cells do not always accurately model real-world scenarios
  - Flow recirculation and inlet non-uniformities are possible
  - Temperature stratification can also be an issue
  - For high speed also be aware that non-moving ground plane could produce different underhood flow patterns
- Check data for consistency using alternative calculation methods– a few bad measurements can change calculated air flow volumes significantly